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PART I

by

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REVIEW OF DEVELOPMENT OF IR GUIDANCE TECHNIQUES PART I

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ABSTRACT: Taking the introduction and comment on the Gulf War (the Desert Storm Operation) as a guide, this paper systematically describes the development of three generations IR Guided Missile, two generations IR Imaging Guided, three generations Anti-tank Missile, as well as SFM (Sensitive Following Missile) and TGM (Terminal Guided Missile) in detail. Finally, the TGM with Combined Guidance are introduced.

[Key Words] The gulf war IR guidance Imaging guidance Combined guidance Anti-tank missile SFM (Sinsitive following missile) TGM(Terminal guided missile)

I. General Description of Precision-Guided Munitions in the Gulf War

In the recent decade there were several wars in the world. In particular, the Gulf War broke out early in 1991; this indicates that modern military strategy has been transformed from

simply emphasizing numerical superiority into superiority in technical quality. High-tech is the deciding factor of victory in present and future wars.

At a duration of 42 days, from January 17 to February 28, in 1991, the Gulf War between multinational forces (led by the United States) and Iraq clearly tells us that precision-guided munitions, often called by the western countries as the star of conventional weapons and as the mark of weaponry modernization, have become the fundamental firepower in modern war. Antitank missiles were the number one killer of antitank and antiarmor combat in this war.

At the beginning of the Gulf War, both sides in the combat used large quantities of precision-guided munitions of various kinds. Based on statistics, there are almost 50 kinds of missiles, guided artillery rounds, and guided bombs used by the multinational troops. Certain noteworthy events are presented in the following:

1) On the first day of the war, from the battleships Missouri and Wisconsin of the United States multinational forces fired 125 Tomahawk BGM-109C cruise missiles, in destructive assaults on scores of strategic targets, such as government buildings and communication centers in Baghdad, missile bases, air force bases, as well as biochemical and nuclear weapon facilities. Until the eve of the conclusion of the war, such missiles were still used to attack the Iraqi presidential palace and the headquarters of the Baath Party. As estimated, possibly

600 to 700 Tomahawk cruise missiles were used in the entire war, with a success rate of approximately 85%. These missiles can cruise for approximately 1000km with a cruise speed of Mach0.7, and a cruise altitude between 50 and 250m. The missile range is 1300km; its length is 6.4m, diameter is 527mm, its weight is 1340kg, and the warhead weight is 454kg. Each Tomahawk costs 1.3 million U.S. dollars.

2) At the beginning of the "Desert Shield" action, one key problem faced by the United States was to cope with the Iraqi aircraft, their tactical guided missiles, and their air defense weapons. Therefore, U.S. forces deployed Patriot and Hawk surface-to-air missile companies in the Gulf War. As is well known, the U.S. Patriot MIM-104 all-weather all-area surface-to-air missiles successfully intercepted Iraq's Scud missiles. As reported, Iraq fired nearly 80 Scud missiles against Saudi Arabia and Israel during the Gulf War period. In nearly 60 Scud missiles intercepted by the Patriots the success rate exceeded 90%. The Patriot missile has a range of 100km, weighs about 1000kg, and its warhead weighs 91kg. Four Patriot missiles are deployed on a trailer-type launch pad. The weapon system applies a multifunctional phase control array radar to search, discriminate, track, and illuminate targets, in addition to tracking and guidance of missiles, as well as counterelectronic jamming. The Patriots can monitor 100 groups of targets in plus or minus 60 degrees of the front, and 0 to 90 degree in elevation

angle, in addition to simultaneous tracking of eight groups of targets and guidance of eight missiles. The detection distance of the main radar antenna is between 150 and 160 kilometers.

3) Before the Gulf War, Iraq had 5600 tanks and 8000 armored vehicles. Thus, Saddam Hussein expected to wage a ground war. To deal with this point, the multinational forces used F-16s, A-10s, F-15Es, and other aircraft to fire Maverick missiles. AH-64A Apache attack helicopters fired Hellfire missiles. By using AH-1S, Gazelle and Puma armed helicopters to fire TOW and HOT missiles. The multinational forces fired TOW, HOT, Milan, and Dragon antitank missiles, as well as Army tactical missiles Atacms with munitions. In the air bombing stage, from January 17 to February 9, 750 tanks and 600 armored vehicles of the Iraqi forces were destroyed. In the ten-day period between February 10 to February 19, another batch of 650 Iraqi tanks and 500 armored vehicles were destroyed. In the ground combat of the last four days (100 hours), the U.S. forces applied air and land integrated tactics. In the air, there were aircraft of three firepower levels. For a distance of about 3500m, AH-1S armed helicopters fired TOW missiles. At a distance of about 5000m, Apache attack helicopters fired Hellfire missiles. For longer distances, A-10 aircraft fired Maverick missiles. For the ground, large-caliber launched weapons were used to attack in the range between 2200 and 3500m. This is the ideal range for TOW missiles. In these four days, more than 40 Iraqi divisions at the front were

annihilated. Thirty-seven hundred of 4800 tanks, more than 2000 of 2800 armored vehicles, and more than 2100 of 3100 artillery pieces were lost. Here, the infrared imaging guidance was the star, with the Maverick AGM-65D air-to-ground missile known as the "fire-and-forget" weapon. After the beginning of the desert action, the U.S. forces used the Maverick to surgically attack such military targets as the Iraqi defense minister's building, broadcast communication facilities, and ammunition dumps. Moreover, AGM-65As and -Bs with television guidance waged intense bombardments on the Iraqi aircraft revetments, missile launchers, artillery emplacements, and tanks. Since the beginning of tactical bombing on February 6, A-10s, F-15s, and F-16s were used in large groups to carry AGM-65Ds to attack ground armored targets. The Maverick is the air-to-ground missile used the earliest in the Gulf War, in the greatest numbers up to the conclusion of the war. As estimated, the total number of Maverick missiles used during the war was as many as 5500. Most of them were AGM-65D versions, with infrared imaging guidance; one-third was the television-guided AGM-65As and -Bs; and the balance was laser-guided AGM-65E, and the large-warhead AGM-65G, with an overall success rate exceeding 80%. The AGM-65D applies 16 (4x4) element optical guidance type CMT detector and 20-phase internal reflection rotating mirror. The missile diameter is OD 305mm, its warhead weighs 56.25kg, and its overall weight is 225kg. Each missile costs 100,000 U.S. dollars. For the AGM-65G, a 136-kg warhead is used; its total weight is 304kg

to attack various emplacements, such as aircraft revetments, fortified areas, and other kinds of revetments.

4) Based on an Aviation Week and Space Technology January 18 report in the United States, on January 17, an A-6E and A-7E attack aircraft took off from the U.S.S. Kennedy aircraft carrier of the U.S. Navy, fired and controlled two infrared imaging guided air-to-ground Slam AGM-84G missiles, to attack a hydroelectric station near Baghdad. The first missile exploded and opened a hole at the outer wall of the power station. Two minutes later, the second missile passed through the hole to destroy equipment in the power station. The SLAM is an improved version of the U.S. Navy's antiship Harpoon missile. Both versions have in common sustainer engine, warhead compartment, radar altimeter, and midsection inertial guidance equipment. What distinguishes them is that the Slam uses the infrared guidance head of the Maverick air-to-ground missile AGM-65F, the video frequency data link of the White Eye Star guided bomb, and the single-channel global positioning system (GPS) receiving and processing unit. The latter can ensure that the midsection guidance precision of the missile is 16m; however, the infrared imaging guidance head and the data link can ensure hitting the target precisely at the final segment. Slam missiles are used on U.S. Navy fighters, with a 100-km range and a 220-kg warhead.

5) During the Gulf War, multinational forces consistently

maintained air superiority, waging large-scale continuous bombing against Iraq. Besides carpet bombing on Iraqi ground defenses along the borders with Saudi Arabia and Kuwait, precision-guided munitions were used for fixed-point bombing on in-depth targets and strategic targets of densely populated areas. To destroy bridges in Iraq, multinational forces used multiple kinds of missiles and smart bombs. It was said that the AS-30L air defense missiles with laser semipowered guidance of French troops destroyed one-third of the bridges in Iraq. The range of such missiles is 10 to 12km, the weight is 520kgt, and the warhead weight is 250kg. It was reported that a total of half a million tons of munitions were used by multinational troops in the Gulf War. The U.S. Air Force dropped nearly 100,000 tons of bombs, including approximately 5900 tons of precision-guided munitions. Besides the above-mentioned AS-30L, in the Gulf War, the U.S. Air Force used large numbers of Paveway-III and GBU-15 smart bombs. From analysis, the combat effectiveness of a laser-guided bomb corresponds to approximately 200 bombs without guidance. The cost effectiveness can be upgraded by a factor of 50. In addition, bomb sorties can be reduced if precision-guided munitions are used.

Generally speaking, there are the following main stages of the entire Gulf War: cruise missiles are the forerunners. Infrared guidance missiles and laser guided bombs extended the combat results. Patriot air defense missiles resisted the enemy's ground-to-ground tactical missiles. Finally, airborne

antitank missiles were the main weapons in decisive ground battles to destroy enemy tanks and armored vehicles, so that a complete victory was attained by the multinational forces. Based on statistics, in the 42 days of the Gulf War, there were 126 fatalities among the multinational forces. This is only 0.018 percent of the total combat personnel of 680,000. Thus we can see that high-tech guided weaponry and modern fighter craft have an alarming function in modern war. Recalling the last two decades, there are two local wars called modern, besides the Gulf War: one is the fourth Mideast war in 1973. The Soviet-made Sager (AT-3) missiles were used by Egypt to ambush an Israeli tank brigade, destroying more than 200 tanks. However, Israel used remodeled French SS-11 antitank missiles to destroy more than 300 tanks of Egypt and Syria. Another war is the Falklands War between the U.K. and Argentina in 1982. The Argentine forces used an Exocet missile to sink the destroyer Sheffield of the British Navy. The British fired 27 Sidewinder AIM-9L air-to-air infrared missiles. Twenty-four of the missiles hit Argentine planes. However, the precision-guided munitions used in these two wars cannot be compared with those of the Gulf War.

II. Development of Optical and Infrared Guidance Technology

Generally speaking, since the optical precision guidance (including visible light, television, laser, and infrared) is high in guidance precision and counter electronic jamming, good concealment, high benefit-to-cost ratio, compact structure,

flexibility, and mobility, it has become an important technical means of precision-guidance weaponry. In the U.S. SDI program, optoelectronic technology occupies a heavier-than-ever proportion, therefore, SDI is called the photonic war program. Specialists predict that optical guidance will assume the major role in precision-guidance weapon technology from the nineties to the 21st century. In particular, infrared precision guidance has unique properties of not being easily jammed by electronics, capability of operating 24-hours a day, good concealment, and high resolution by using the approach of passive homing, the technique is the guidance approach with the most promising aspect in optical precision guidance. Up to now, the development of infrared guidance can be classified generally in two stages with corresponding development of three generations of guided weapons, including two generations of infrared imaging guidance. These generations are related to the development of infrared detector technology, and their performance in hitting targets. The following is a brief description:

1) The first period is before the mid-sixties. In this period, infrared guidance weapons were mainly used to attack relatively slow-flying aircraft. In most cases, the infrared elements were PbS with operating waveband between 1 and 3micrometers. The representative model of this generation of guided weapons is the Redeye (U.S.) and the SAM-7 (Soviet Union) ground-to-air missiles, as well as the Sidewinder series of the

U.S. air-to-air missiles. These missiles can attack an aircraft target by tailing, with small angles of attack. They are severely affected by background and meteorological conditions, and have weak capability of counterjamming (especially against jamming by sunlight reflected from clouds). Therefore, their tactical performance was greatly limited.

2) The second period is from the mid-sixties to the mid-seventies. In this period, the aircraft speed and mobility were greatly upgraded, together with the use of infrared decoys so that the combat effectiveness of the first-generation infrared guidance missiles was significantly downgraded. Thus one of the measures of improvement was the cryogenic treatment of the PbS elements, to upgrade their sensitivity. The most fundamental measure was to use InSb elements operating in the waveband between 3 and 5micrometers, with improved adjustment disk, thus upgrading antijamming capability and increasing the angle of attack against aircraft so that attacks can be made in the entire rear hemisphere between plus and minus 90°. Improvements were also made in signal processing so that the combat performance of second-generation missiles developed with greater enhancement. The representative models are the Stinger (U.S.) and Mistral (France) ground-to-air missiles.

Both the first- and second-generation infrared precision guided weapons consider the targets to be attacked as point sources. An adjustment disk or a conical scanner was used to

modulate the phase, frequency, amplitude, and pulse duration of the point source signal in order to acquire orientation information of the target. If there is an intensive radiation infrared jamming, especially during attack by ground targets of tanks and armor, with complicated infrared backgrounds, this system is not effective.

3) The third period is after the mid-seventies. At that time, long-wave infrared elements operating between 8 and 14micrometer waveband were successfully developed. In particular, applications of high-performance HgCdTe (CMT) linear array infrared apparatus and infrared imaging technique have been gradually matured, thus having a leap forward in infrared guidance technology, with the emergence of the third-generation infrared guidance weapons of infrared subimaging and infrared imaging with precision guidance. One of the schemes in the third generation is the use of dual color (infrared/ultraviolet or dual-color infrared) rose-coil-shaped scanning in the subimaging guidance system, such as the improved version of the Stinger (Stinger-Post of the U.S.), the improved version of the Mistral (of France) and the SAM-13 (of the Soviet Union). In another arrangement, linear array or small-area infrared devices are used with the imaging guidance system of optical scanning imaging, such as the Maverick AGM-65D/F of the U.S. in using 16 (4x4) element optical guidance CMT infrared devices, and 20 phases internal rotating drum reflective mirror to realize scanning

images of ground targets. In the late eighties, staring-type infrared focal-plane array (IRFPA) detectors were successfully developed in the U.S. and Western Europe by using electronic self-automatic scanning to replace optical device scanning in the second-generation infrared imaging guidance weapon system. The representing models are the advanced intermediate-range antitank missile weapon system (AAWSM of the U.S.) and the long-range antitank missile Trigat of the U.K, France, and Germany, under development. The AAWSM is expected to complete its engineering development in 1992 by using 64x64 element CMT single-lens CCD staring infrared focal-plane array of the U.S.

Infrared imaging guidance is different from infrared guidance. Previously infrared guidance can consider only the target as a hot point in processing, therefore details of target background unable to be clarified, thus easily jammed by the background and false targets. However, the infrared imaging guidance utilizes the temperature difference of thermal radiation between target and background, to form a picture of the target and its surrounding scene in the automatic guidance. Not only are sensitivity and resolution high, with large activity scope and high antijamming capability, but also having the property of actively capturing the target for automatic decision making in complex situations along with better operating capability, either in day or night. According to different application requirements, this system can lock on the target before launch or after launch, with the realization of fire-and-forget or fire-

and-run. The adaptability of models is also very high; by only changing the discrimination and tracking software of the control guidance system, the hardware can be used in different missile models.

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